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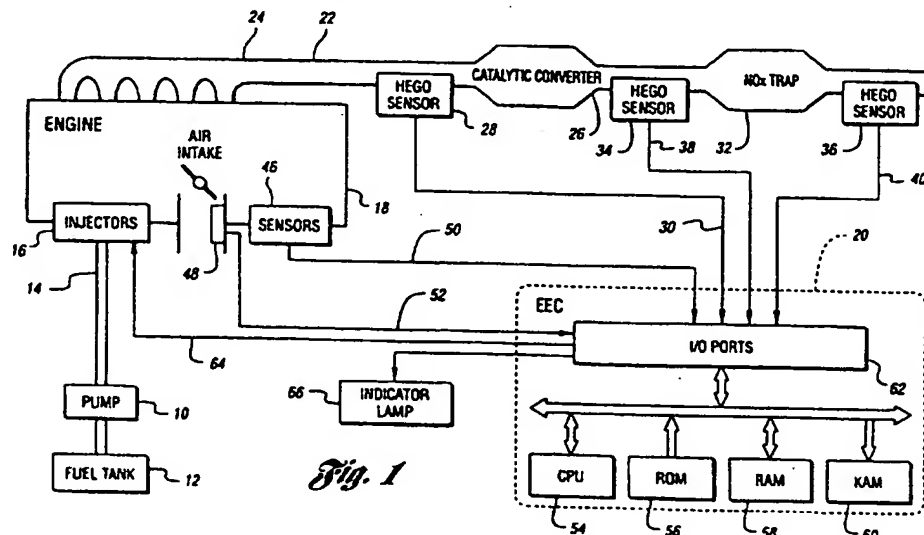
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## (54) Method and system for monitoring the performance of a NO<sub>x</sub> trap

(57) A method and apparatus for on-board monitoring of NO<sub>x</sub> trap 32 performance is proposed that uses two HEGO sensors 34,36, one positioned upstream of the NO<sub>x</sub> trap, and the other positioned downstream of the NO<sub>x</sub> trap. When the engine A/F is reduced from lean to stoichiometric or rich operation to regenerate or purge the NO<sub>x</sub> trap the difference in the time it takes for the upstream and downstream HEGO sensors to switch from a lean to a rich indication provides a quantitative measure of the amount of NO<sub>x</sub> that was stored on the NO<sub>x</sub> trap 32 during the previous lean period of operation. This measure is related to an estimated amount of NO<sub>x</sub> produced by the engine to infer the operating performance or efficiency of the NO<sub>x</sub> trap. The difference in the output voltage of the two sensors 34,36 is compared with a predetermined value to determine when to terminate the NO<sub>x</sub> purge. When the efficiency drops below a predetermined value the time that the engine is run in a lean cruise mode is reduced. If the time is reduced below a minimum time interval, a sulfur purge is performed. If sulfur purges are required more often than a predetermined repetition time, the lean cruise mode is terminated and an indicator lamp is energized.



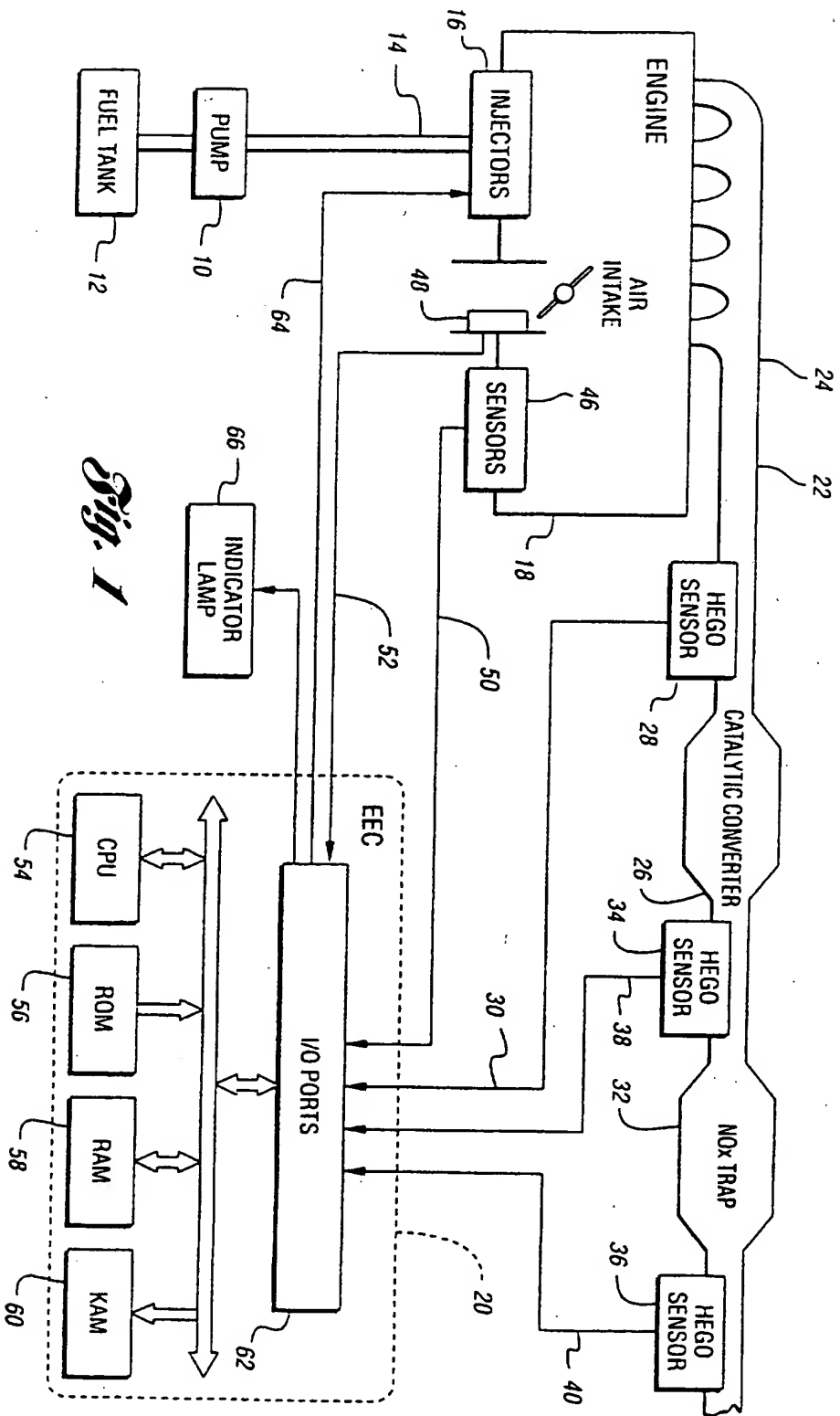
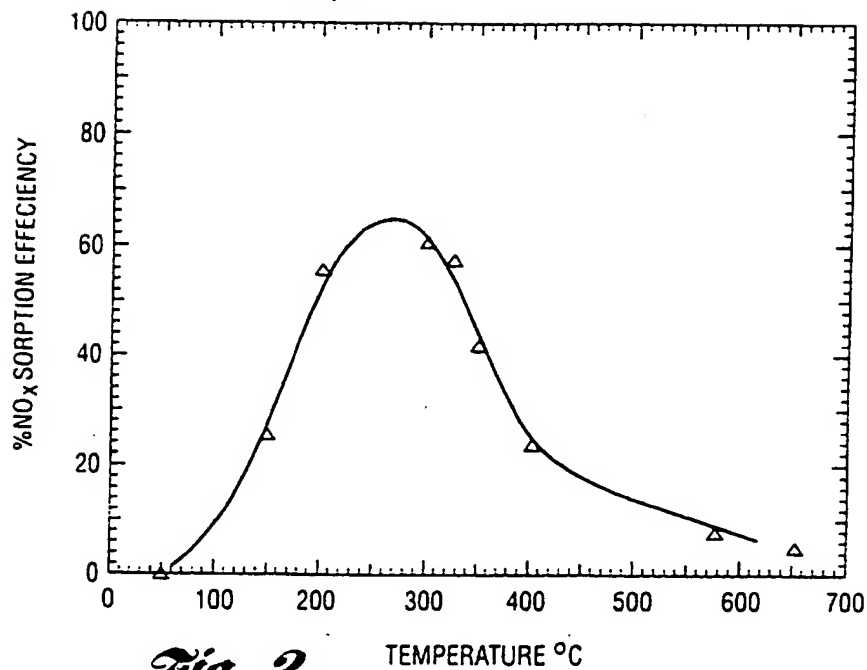
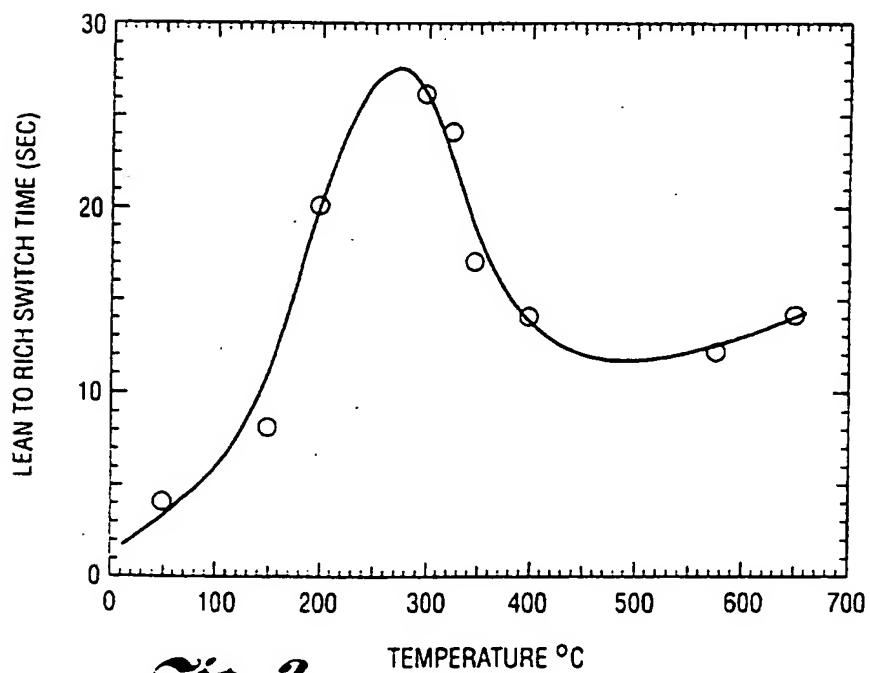


Fig. 1

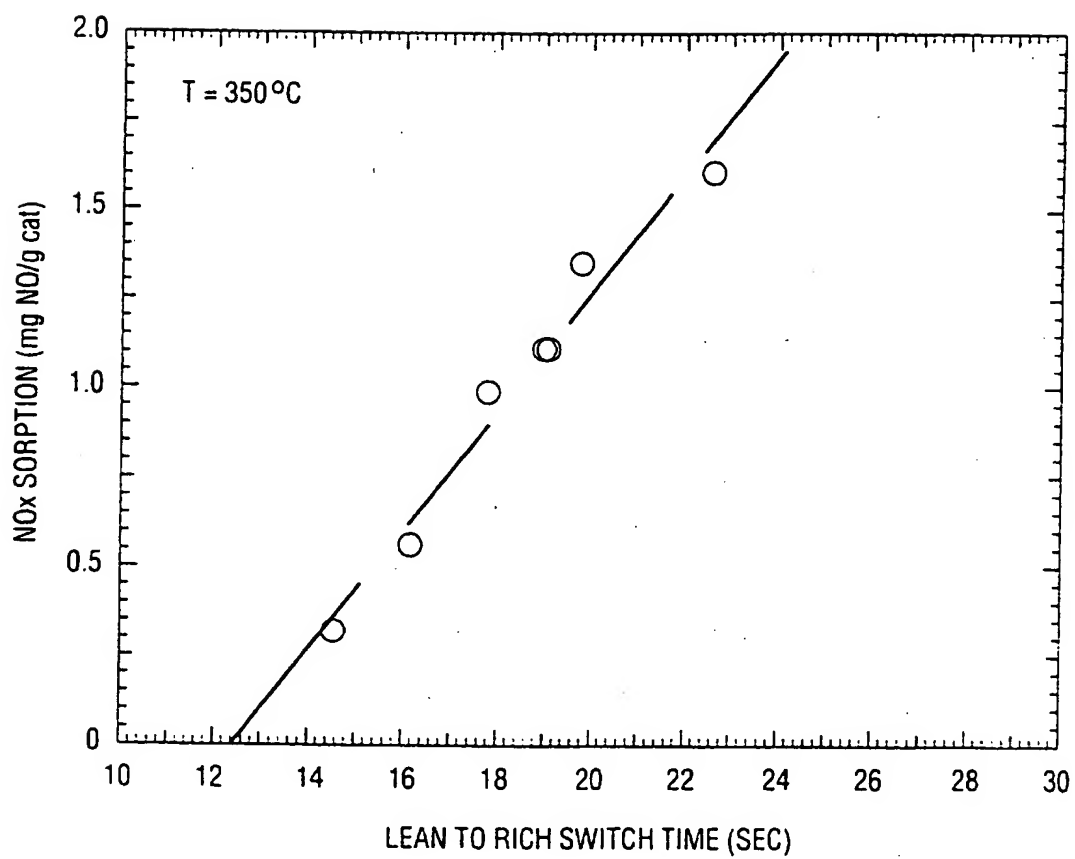
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*Fig. 2*



*Fig. 3*

*Fig. 4*

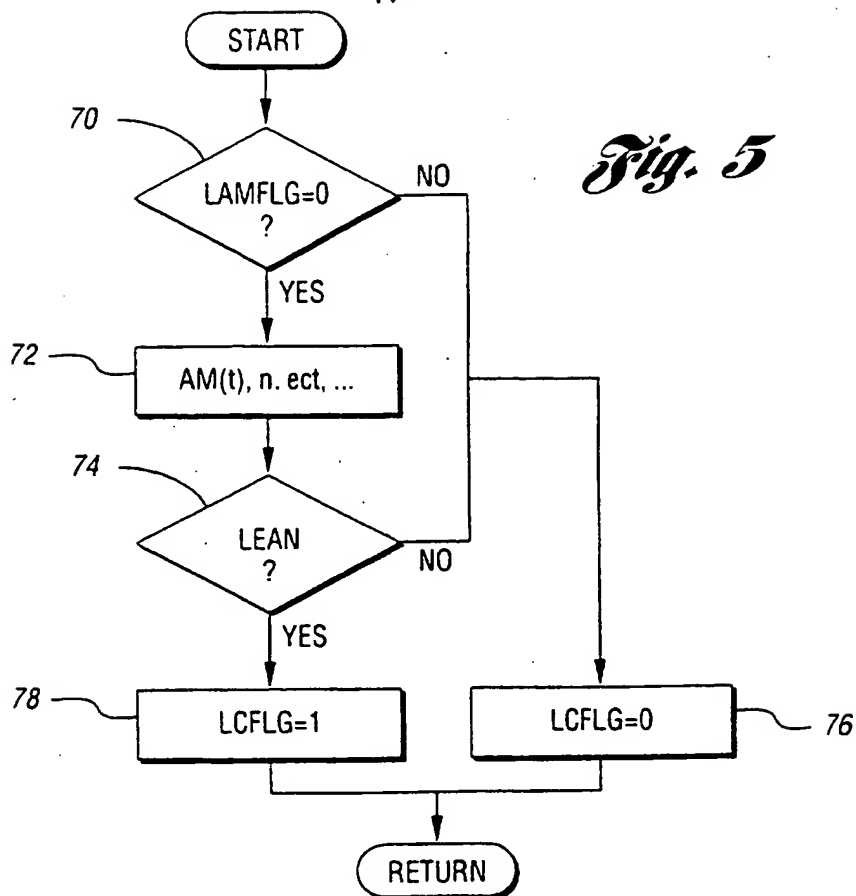
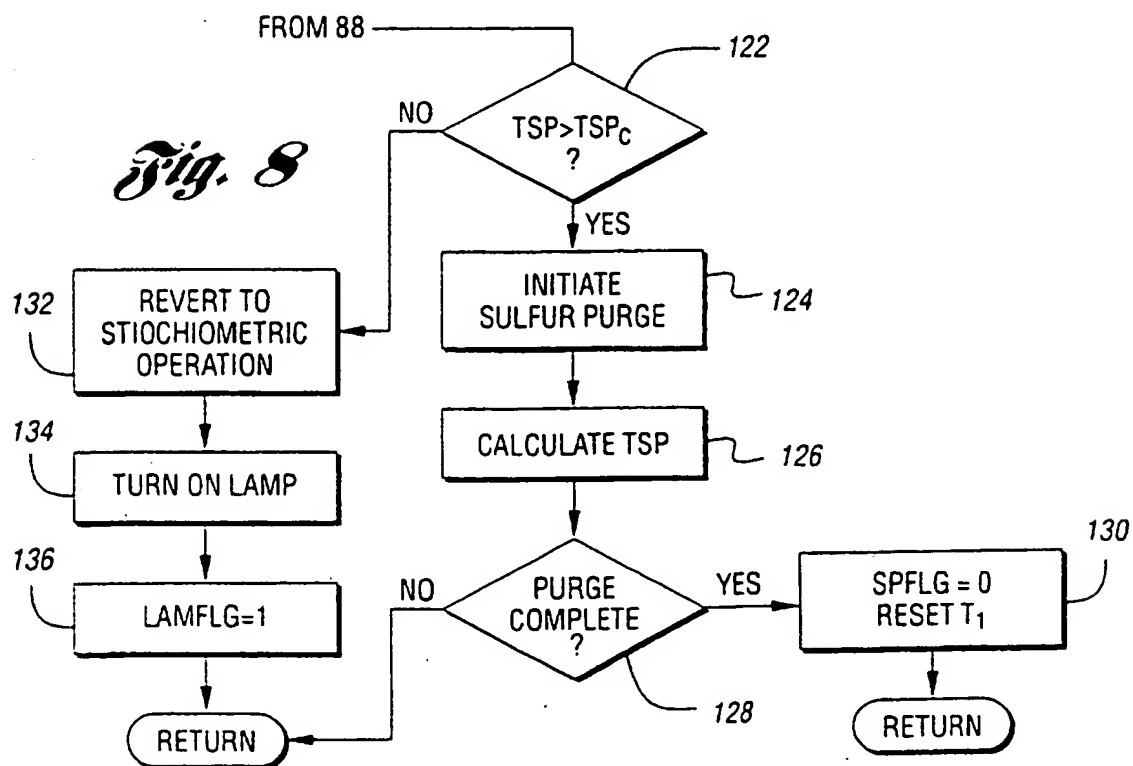
*Fig. 5**Fig. 8*

Fig. 6a

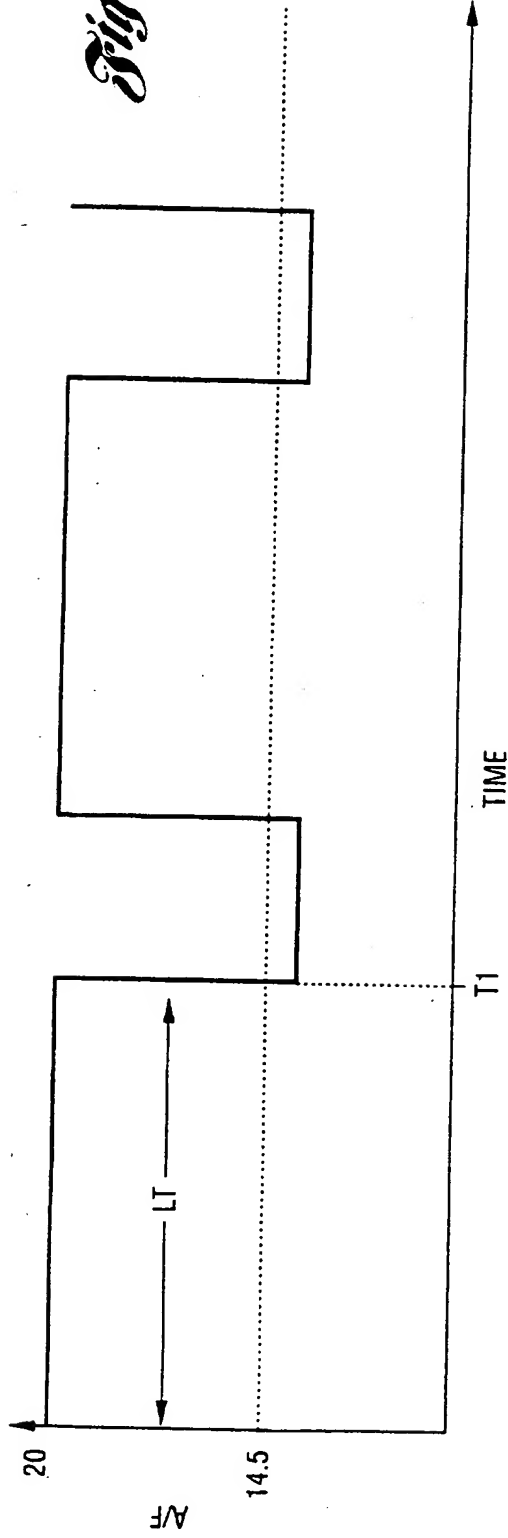


Fig. 6b

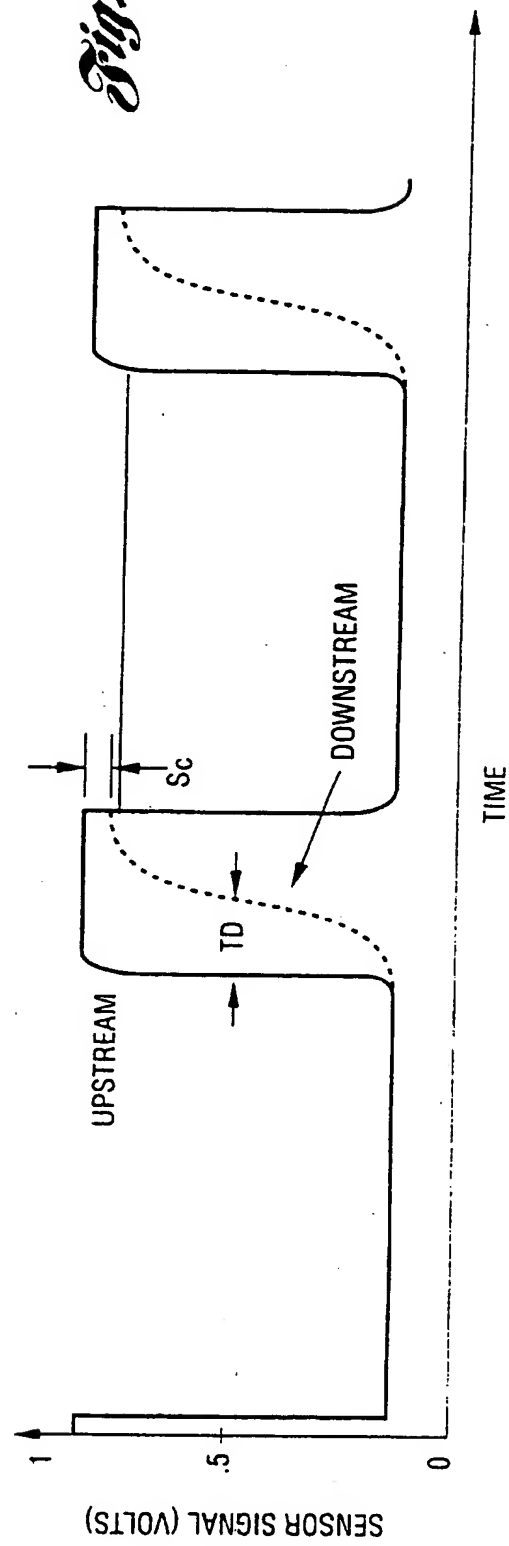
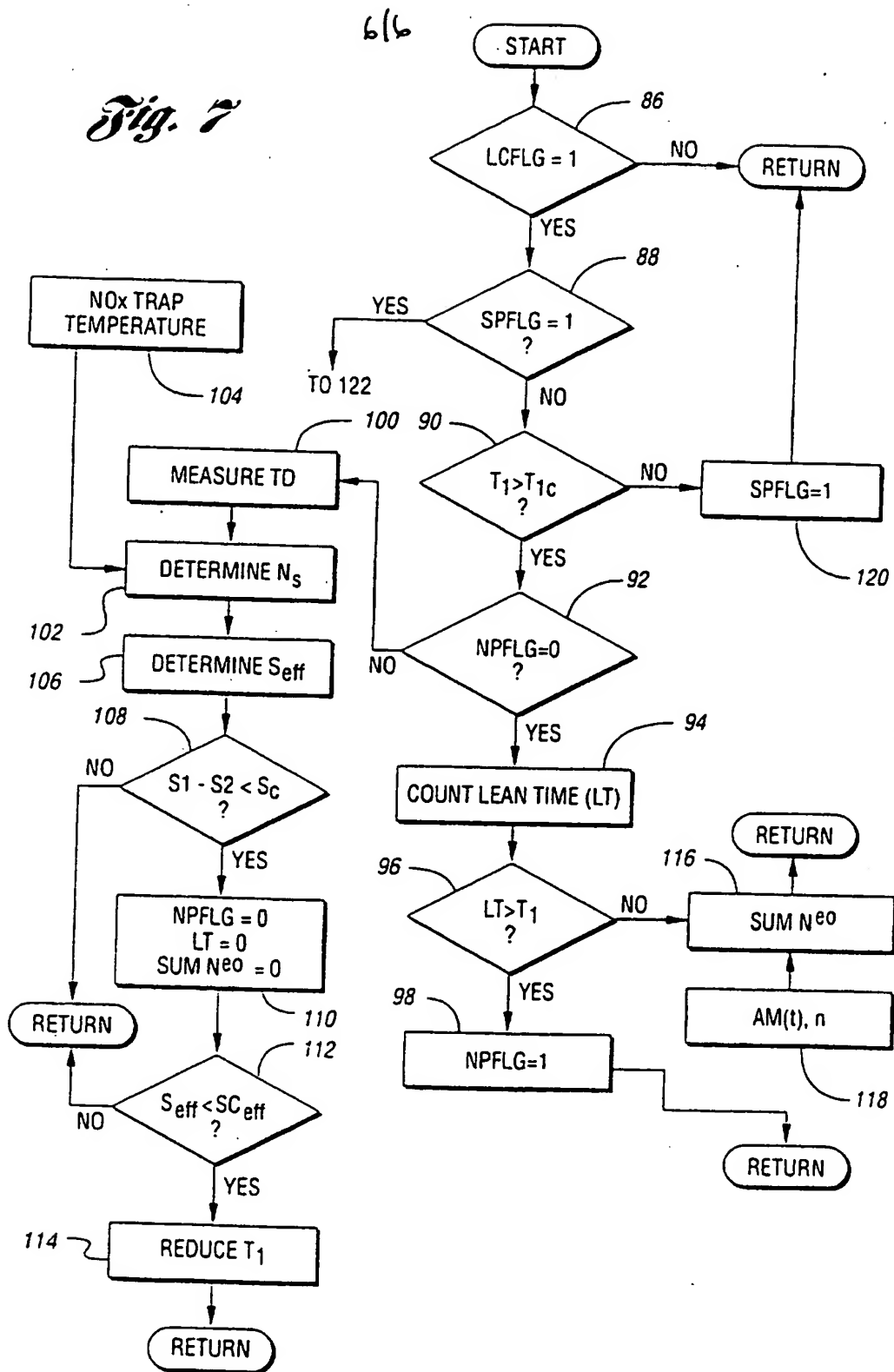


Fig. 7



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METHOD AND SYSTEM FOR MONITORING THE  
PERFORMANCE OF A NO<sub>x</sub> TRAP

5 This invention relates to monitoring the status and  
performance of exhaust gas purification devices installed in  
the exhaust passage of an internal combustion engine.

10 Presently, NO<sub>x</sub> traps are considered a potential exhaust  
after-treatment technology for lean burn engines. NO<sub>x</sub> trap  
technology typically utilizes alkali metal or alkaline earth  
materials in combination with platinum in order to store or  
occlude NO<sub>x</sub> under lean operating conditions. The mechanism  
for NO<sub>x</sub> storage involves the oxidation of NO to NO<sub>2</sub> over the  
15 platinum followed by the subsequent formation of a nitrate  
complex with the alkaline metal or alkaline earth; under  
stoichiometric or rich conditions, the nitrate complexes are  
thermodynamically unstable, and the stored NO<sub>x</sub> is released  
and is catalytically reduced by the excess of CO, H<sub>2</sub>, and HCs  
in the exhaust.

20

If the NO<sub>x</sub> trap deteriorates over time, the ability to  
trap pollutants degrades with resultant increase in  
atmospheric pollution. Therefore, it is desirable that NO<sub>x</sub>  
trap technology implemented provide an on-board computer  
25 driven diagnostic indication of deterioration or degradation  
of the NO<sub>x</sub> trap beyond a predetermined limit.

In accordance with the present invention, a method and  
apparatus is provided for making on-board measurements of NO<sub>x</sub>  
30 trap sorption that permits vehicle on-board computer  
monitoring and evaluation of NO<sub>x</sub> trap performance.



It has been found that during NO<sub>x</sub> trap purging, the lean to rich response time ( $T_{LR}$ ) of a HEGO (Heated Exhaust Gas Oxygen) sensor positioned downstream from the NO<sub>x</sub> trap is reduced by an amount which is proportional to the quantity  
5 of NO<sub>x</sub> stored on the trap. As NO<sub>x</sub> sorption efficiency increases, more NO<sub>x</sub> is stored on the trap, and the  $T_{LR}$  of the downstream HEGO sensor increases as well.

Based on the above discovery, the present invention  
10 proposes to use this time interval between the initiation of the purge operation and the switching of the downstream HEGO sensor as an indicator of the amount of NO<sub>x</sub> which was stored onto the NO<sub>x</sub> trap during the previous lean period of operation. Also, this time delay is used in a diagnostic  
15 routine for indicating degradation of the NO<sub>x</sub> trap performance to an extent requiring attention by service personnel.

More particularly, in a preferred embodiment of the  
20 invention two HEGO sensors, one positioned upstream of the NO<sub>x</sub> trap, the other positioned downstream of the NO<sub>x</sub> trap are employed. When the engine A/F is reduced from lean to stoichiometric or rich operation to regenerate the NO<sub>x</sub> trap (i.e. in order to remove the stored NO<sub>x</sub> and subsequently  
25 convert it to N<sub>2</sub>), the difference between  $T_{LR}$  for the upstream and downstream HEGO sensors provides a quantitative measure of the amount of NO<sub>x</sub> that was stored on the NO<sub>x</sub> trap during the previous lean period of operation. This estimation of the amount of NO<sub>x</sub> stored by the trap is related  
30 to a predicted amount of NO<sub>x</sub> produced by the engine to infer the operating performance or efficiency of the NO<sub>x</sub> trap. Also, the output voltage signal differential between the

downstream and the upstream HEGO sensor is checked to  
determined when to terminate the NO<sub>x</sub> purge.

5 If trap sorption efficiency drops below a predetermined  
efficiency, the lean operation time is reduced in an attempt  
to improve efficiency. If and when the reduced lean time  
duration drops below a predetermined minimum lean operation  
time, a sulfur purge of the trap is desirable and is  
performed.

10

If the interval between successive sulfur purges  
becomes less than a predetermined interval, this is  
indicative of deterioration of the trap beyond that which  
can be remedied by the normal purging operations.  
15 Accordingly, the lean cruise mode of engine operation is  
terminated and operation reverts to a closed loop  
stoichiometric mode and an indicator lamp is energized, so  
that appropriate remedial action can be taken by the  
operator.

20

The invention will now be described further, by way of  
example, with reference to the accompanying drawings, in  
which:

Figure 1 is an overall block diagram of the control  
25 system of the present invention;

Figures 2 and 3 graphically demonstrate the similar  
quantitative relationship between %NO<sub>x</sub> sorption efficiency  
and the lean to rich switch time of a downstream oxygen  
sensor over a range of temperature;

30

Figure 4 shows that the lean to rich switch time of a  
downstream oxygen sensor is substantially directly  
proportional to the amount of NO<sub>x</sub> that is stored on the trap;

Figure 5 is a flowchart depicting the conditions under which a lean cruise mode of engine operation is entered;

Figures 6a and 6b are timing diagrams showing the timing of the initiation and termination of the NO<sub>x</sub> purge operation;

Figure 7 is a flowchart depicting the conditions under which the time interval for lean mode is adjusted; and

Figure 8 is a flowchart depicting the conditions under which a sulfur purge is carried out as well as the circumstances under which the lean cruise mode is terminated and an indicator lamp is energized.

Referring now to the drawings and initially to Figure 1, a block diagram of the present invention is shown. A fuel pump 10 pumps fuel from a tank 12 through a fuel line 14 to a set of injectors 16 which inject fuel into an internal combustion engine 18. The fuel injectors 16 are of conventional design and are positioned to inject fuel into their associated cylinder in precise quantities as determined by an electronic engine controller (EEC) 20. The fuel tank 12 contains liquid fuels, such as gasoline, methanol or a combination of fuel types.

An exhaust system 22, comprising one or more exhaust pipes and an exhaust flange seen at 24, transports exhaust gas produced from combustion of an air/fuel mixture in the engine to a conventional three-way catalytic converter 26. The converter 26 contains catalyst material that chemically alters the exhaust gas to generate a catalyzed exhaust gas. A heated exhaust gas oxygen (HEGO) sensor 28, detects the oxygen content of the exhaust gas generated by the engine 18, and transmits a representative signal over conductor 30 to the EEC 20. A NO<sub>x</sub> trap 32 is located downstream of the

converter 26 for trapping nitric oxide contained in the exhaust gas exiting the converter. A HEGO sensor 34 detects the oxygen content of the exhaust gas upstream of the trap 28 while a HEGO sensor 36 detects the oxygen content of the exhaust gas downstream of the trap 28. The sensor 34 and 36 transmits signals over respective conductors 38 and 40 to the EEC 20.

Still other sensors, indicated generally at 46, provide additional information about engine performance to the EEC 20, such as crankshaft position, angular velocity, throttle position, air temperature, etc. over conductor 50. The information from these sensors is used by the EEC 20 to control engine operation.

A mass air flow sensor 48 positioned at the air intake of engine 18 detects the amount of air inducted into an induction system of the engine and supplies an air flow signal over conductor 52 to the EEC 20. The air flow signal is utilized by EEC 20 to calculate a value that is indicative of the air mass flowing into the induction system in lbs./min.

The EEC 20 comprises a microcomputer including a central processor unit (CPU) 54, read only memory (ROM) 56 for storing control programs, random access memory (RAM) 58, for temporary data storage which may also be used for counters or timers, and keep-alive memory (KAM) 60 for storing learned values. Data is input and output over I/O ports generally indicated at 62, and communicated internally over a conventional data bus generally indicated at 64. The EEC 20 transmits a fuel injector signal to the injectors 16 via signal line 64. The fuel injector signal is varied over

time by EEC 20 to maintain an air/fuel ratio determined by the EEC 20. An indicator lamp generally indicated at 66 is controlled by the EEC 20 to provide an indication of the condition of the NO<sub>x</sub> trap 32 as determined by input data from the various sensors as described more fully hereinafter.

The program stored in ROM 58 implements an air/fuel strategy where the engine is operated in lean mode or relatively high air to fuel ratio (A/F) for fuel economy under certain engine speed/load conditions. During the lean mode, NO<sub>x</sub> and SO<sub>x</sub> accumulates in the NO<sub>x</sub> trap. After predetermined criteria are met, indicative of substantially total sorption of the trap 32, the A/F is switched to a relatively rich mixture to purge the trap of NO<sub>x</sub>. After the purge mode is completed the EEC returns to the lean mode of operation. Alternatively, the EEC program may call for a stoichiometric mode of operation instead of the rich mode for purging the trap of NO<sub>x</sub>.

Referring now Figures 2, 3, and 4, the relationship between lean to rich switch time ( $T_{LR}$ ) of a HEGO sensor placed downstream of a NO<sub>x</sub> trap and the quantity of NO<sub>x</sub> stored on the trap is graphically illustrated. Figures 2 and 3 contrast NO<sub>x</sub> trap sorption efficiency as a function of temperature to the corresponding lean to rich switch time ( $T_{LR}$ ) of a HEGO sensor placed downstream of the NO<sub>x</sub> trap. The NO<sub>x</sub> trap sorption efficiency and the downstream HEGO's  $T_{LR}$  exhibit very similar qualitative behaviors. As NO<sub>x</sub> sorption efficiency increases, more NO<sub>x</sub> is stored on the trap, and the  $T_{LR}$  of the downstream HEGO sensor increases as well.

Figure 2 shows the average  $\text{NO}_x$  sorption efficiency as a function of temperature during a 5 minute lean cycle for a conventional strontium based  $\text{NO}_x$  trap. With increasing temperature,  $\text{NO}_x$  sorption efficiency first increases, reaches a maximum level at approximately 300-350°C, and then decreases. These measurements were made in a laboratory flow reactor with a simulated exhaust gas consisting of 10% $\text{H}_2\text{O}$ , 10%  $\text{CO}_2$ , 500ppm  $\text{NO}_x$ , 7% $\text{O}_2$ , in a balance of  $\text{N}_2$ . To purge or regenerate the  $\text{NO}_x$  trap, the  $\text{O}_2$  in the exhaust gas was turned off and replaced with 0.58%  $\text{CO}$ . The space velocity was 30,000hr<sup>-1</sup>.

Figure 3 shown a graph of the corresponding lean to rich switch time ( $T_{\text{LR}}$ ) for a conventional Exhaust Gas Oxygen Sensor (EGO) placed downstream of the  $\text{NO}_x$  trap.  $T_{\text{LR}}$  is defined as the time period between the initiation of the  $\text{NO}_x$  trap purge and the observation of a minimum 0.5 volt sensor output signal. The  $\text{NO}_x$  trap sorption efficiency and  $T_{\text{LR}}$  display very similar qualitative behaviors. As  $\text{NO}_x$  trap sorption efficiency increases, more  $\text{NO}_x$  is stored onto the trap, and the  $T_{\text{LR}}$  of the downstream EGO sensor increases as well. It is believed that the  $\text{NO}_x$  which is stored onto the trap behaves very much like stored oxygen and simply reacts with the  $\text{CO}$  and  $\text{H}_2$  in the exhaust during purging hence delaying rich breakthrough.

Figure 4 shows a graph of  $\text{NO}_x$  storage as a function of  $T_{\text{LR}}$  at 350°C. The lean operating period was varied in order to vary the quantity of  $\text{NO}_x$  stored onto the trap. At a given temperature, the  $T_{\text{LR}}$  which is observed during purging of the  $\text{NO}_x$  trap is seen to be directly proportional to the quantity of  $\text{NO}_x$  which was stored onto the trap during the previous lean period of operation. The present invention utilizes

this relationship between  $\text{NO}_x$  sorption and  $T_{LR}$  to control trap purge time, to determine whether the time interval of lean operation should be reduced, and to determine when the trap should be replaced. Also, this relationship is used to  
5 determine when to de-sulfate the trap to rid the  $\text{NO}_x$  trap of  $\text{SO}_x$ .

Referring now to Figure 5, a flowchart depicting the criteria for entering the lean cruise mode of operation is  
10 shown. The lean cruise mode of operation includes an open loop fuel control mode where the engine is operated with a lean fuel mixture of for example 20 parts air to 1 part fuel. The lean cruise mode of operation also includes a closed loop fuel control mode, which is periodically entered  
15 from the open loop mode, where the engine is operated at a stoichiometric air fuel ratio of about 14.5 to 1 for a time interval sufficient to purge the  $\text{NO}_x$  trap of  $\text{NO}_x$  prior to return to the lean mode. There is a flag LCFLG that reflects the status of the lean cruise mode. While in the  
20 lean cruise mode, the engine is normally operating in an open loop lean mode and is periodically placed in a closed loop stoichiometric mode or slightly open loop rich mode for purging the  $\text{NO}_x$ .

25 At block 70, an indicator lamp flag LAMFLG is checked. This flag is set whenever the EEC 20 determines that the  $\text{NO}_x$  trap has degraded to a point where the normal  $\text{SO}_x$  purging operations are no longer sufficient and the  $\text{NO}_x$  trap requires further attention and may need to be replaced. Such a  
30 condition would be indicated to the vehicle operator by the energized state of the indicator lamp 66 and the occurrence of  $\text{NO}_x$  degradation would be logged in the keep-alive memory 60. IF LAMFLG is reset(0), indicating normal  $\text{NO}_x$  trap

operation, then at block 72 the air mass inducted into the engine, as well as other engine operating conditions, such as speed and engine coolant temperature, are measured to determine the proper engine air fuel ratio (A/F). If degradation of the NO<sub>x</sub> trap has occurred (LAMFLG=1), or if conditions are such that lean operation is not desirable, as determined by the decision block 74, then a lean cruise flag LCFLG is reset(0) at block 76 and the subroutine returns to the main program. Otherwise, the lean cruise flag LCFLG is set(1) at block 78 and the subroutine returns to the main program. The lean cruise mode of operation includes operating at a lean A/F for a length of time T<sub>1</sub>, during which time the engine speed and load are used to estimate the cumulative amount of NO<sub>x</sub> produced by the engine. After the time interval T<sub>1</sub> has expired, a purge of the NO<sub>x</sub> trap is performed by operating the engine at a relatively rich A/F for a purge interval before returning to the relatively lean operation.

A timing diagram of the NO<sub>x</sub> purge operation is shown in Figures 6a and 6b. Figure 6a shows an air/fuel ratio schedule as a function of time, while the engine is in operation in a lean cruise mode of operation at an open loop air/fuel ratio of 20. When lean time LT becomes greater than T<sub>1</sub> a purge of the trap is appropriate so the air/fuel ratio is stepped from a lean value to a slightly rich value, where an air/fuel ratio of 14.5 represents stoichiometry. When this occurs the upstream sensor 34 switches immediately from low voltage to a high voltage, as shown in Figure 6b. As indicated by the dotted line, the switching of the downstream sensor is delayed by the amount TD. The time delay required for the downstream sensor 36 to reach a predetermined voltage, for example, one-half volt as



shown in Figure 6b is measured (block 100). When the output voltage difference between the downstream sensor 36 and upstream sensor 34 reaches a predetermined value  $S_c$  (block 108) the  $\text{NO}_x$  purge is terminated and lean operation is resumed.

Referring now to Figure 7, a flowchart depicting the criteria for purging the  $\text{NO}_x$  trap and the calculation of  $\text{NO}_x$  storage efficiency, is shown. At block 86, LCFLG is checked to determine if the system is being operated in a lean cruise mode. If not, the routine returns to the main program. If so, a sulfur purge flag SPFLG is checked at decision block 88. If SPFLG is set(1), then a sulfur purge of the trap is initiated as will be described hereinafter. If SPFLG is reset(0), the time duration of the lean mode of operation  $T_1$ , is compared with a predetermined minimum time period  $T_{1c}$ . Unless  $T_1$  is greater than this predetermined time interval  $T_{1c}$ , lean cruise operation may need to be terminated. The time interval  $T_1$  is initially a predetermined value and will remain so as long as  $\text{NO}_x$  trap storage efficiency remains above a predetermined or required efficiency value, but  $T_1$  will be reduced as explained below in order to maintain the required efficiency. If it is determined at block 90 that  $T_1$  is not greater than the predetermined time period  $T_{1c}$ , this may indicate that the  $\text{NO}_x$  trap is deteriorated due to the adsorption of  $\text{SO}_x$ , an undesirable but unavoidable process. Accordingly, the sulfur purge flag is set and the lean and  $\text{NO}_x$  flags are reset at block 120 and the operation returns to the main program. The next time through this routine a sulfur purge will be called for at the decision block 88.

If  $T_1$  is greater than  $T_{1c}$ , then the conditions of a  $\text{NO}_x$  purge flag (NPFLG), is checked at decision block 92. If the  $\text{NO}_x$  purge flag is reset, that is, the engine is operation in a lean mode, lean time LT is incremented at block 94 and compared to  $T_1$  at block 96. If the lean time is not greater than the predetermined time period for lean operation as determined by the block 96, then an estimate of the amount of  $\text{NO}_x$  which has been introduced to the trap since the last purge is made in block 116.  $\text{SUM } N^{e0}$ , determined in block 116, is a prediction of cumulative  $\text{NO}_x$  produced by the engine based on air mass inducted into the engine and engine speed as input from block 118. If, on the other hand, the measured lean operating time is greater than the set time period for lean operation  $T_1$ , as determined at block 96, the NPFLG flag is set as shown at block 98 and the  $\text{NO}_x$  purge operation is begun by switching from a lean mode to a relatively rich A/F. The next time through the loop at block 92 the NO path will be taken.

During the  $\text{NO}_x$  purge, the time delay that occurs between switching of the front and rear EGO sensors, due to  $\text{NO}_x$  accumulation, is measured at block 100. Based on this time delay, the amount of  $\text{NO}_x$  stored on the trap  $N_s$  is determined at block 102 as a function of the trap temperature (Figure 4), which is input from block 104. The trap temperature may be obtained in several known ways such as from a temperature sensor or based on sensed air mass or estimated by way of another input.

The  $\text{NO}_x$  storage efficiency  $S_{eff}$  is determined at block 106 based on the ratio  $N_s/\text{SUM } N^{e0}$ . In other words, storage efficiency is ratio of the amount of  $\text{NO}_x$  stored in the trap to the amount of  $\text{NO}_x$  generated by the engine. At decision

block 108, the voltage S2, of the downstream HEGO sensor 36 is subtracted from the voltage S1, of the upstream HEGO sensor 34 and the difference is compared to a predetermined difference  $S_c$  to determine whether it is time to terminate  
5 the NO<sub>x</sub> purge. As soon as the difference drops below the predetermined difference value, the purge may be considered complete and is terminated and the NO<sub>x</sub> purge flag NPFLG is reset(0), the lean cruise time counter or timer LT is reset, and the predicted NO<sub>x</sub> value SUM N<sup>eo</sup> is reset at block 110.

10

If the NO<sub>x</sub> storage efficiency is less than a predetermined NO<sub>x</sub> storage efficiency  $SC_{eff}$  as determined by the block 112, then the time period for lean operation,  $T_1$ , is reduced toward  $T_{1c}$ , by a predetermined amount, at block  
15 114. If the lean time interval has been reduced below the predetermined time period  $T_{1c}$  as determined by the block 90 then the sulfur purge flag (SPFLG) is set as indicated in the block 120. With SPFLG = 1, the next time through this routine a sulfur purge will be called for at the decision  
20 block 88.

Referring now to Figure 8, the subroutine for carrying out a sulfur purge and on-board NO<sub>x</sub> trap diagnostics is shown. Sulfur purge is accomplished by raising the NO<sub>x</sub> trap  
25 temperature to a predetermined level, for example above 550 degrees C, while exposing the NO<sub>x</sub> trap to a rich exhaust gas mixture. Additional air from a separate air supply and pump may be introduced under EEC control to achieve desired trap temperature in order to generate an exotherm on the NO<sub>x</sub> trap  
30 32 and hence achieve the desired temperature.

If the lean cruise flag (LCFLG) is set(1), and the sulfur purge flag (SPFLG) is set(1), as determined by blocks

86 and 88 of Figure 6, a sulfur purge is initiated at block 124, unless the time period between successive sulfur purges (TSP) is less than a predetermined time period ( $TSP_c$ ) as determined by the block 122. At block 126 the time since the last sulfur purge (TSP) is calculated. When the purge is completed as determined by block 128, the sulfur purge flag (SPFLG) is reset(0) at block 130 and the subroutine returns to the main program. Completion of sulfur purge would be based on the trap 32 being above a threshold temperature for a predetermined time period or on other criteria. On the other hand, if the time period between sulfur purges is less than the predetermined time period  $TSP_c$ , this frequent need to perform a  $SO_x$  purge is an indication that the trap is not being properly purged and may be defective. In this event the system reverts to a stoichiometric operation at block 132, the indicator lamp is energized at 134, and the associated flag (LAMFLG) is set at 136. This will cause the lean cruise flag LCFLG to be reset(0) at block 76 (Figure 5) the next time a decision is called for at block 70. Thus, a diagnostic lamp is energized whenever the  $NO_x$  trap exhibits an apparent permanent loss in activity which is not alleviated by the  $NO_x$  and  $SO_x$  purging operations normally intended to revitalize the trap.

25

While two HEGO sensors 34 and 36 are shown, the sensor 34 could be eliminated. In this particular case, the time interval measured at block 100 would be simply the time delay between the initiation of the  $NO_x$  purge (switching engine A/F ratio from lean to rich or stoichiometric) and the lean to rich switch of the rear HEGO sensor 36. Also, a minimum output signal or voltage of sensor 36 would be checked at block 108 to determine that an adequate  $NO_x$

30

purging had been completed. Further, the NO<sub>x</sub> purging operation may commence based on other criteria than a predetermined time interval in lean mode. This change would involve a modification of the operations performed at blocks  
5 90, 96 and 114 to reflect the new criteria.

CLAIMS

1. A vehicle on-board computer method of diagnosing the status of a NO<sub>x</sub> trap disposed in an exhaust passage of an internal combustion engine, comprising a sequence of the following steps:

performing a purge of said trap after meeting predetermined lean mode engine operating criteria; and

providing an indication of trap deterioration if the time interval between successive purges is less than a predetermined time interval.

2. A method as claimed in Claim 1, wherein said purge is a SO<sub>x</sub> purge.

3. A method as claimed in Claim 2, including the further step of performing a NO<sub>x</sub> purge prior to said SO<sub>x</sub> purge.

4. A method as claimed in Claim 3, wherein said NO<sub>x</sub> purge is initiated periodically during a lean cruise mode of engine operation and the time interval of lean operation is adjusted to improve trap sorption efficiency whenever trap sorption efficiency drops below a predetermined trap sorption efficiency.

5. A method as claimed in Claim 3, wherein said SO<sub>x</sub> purge is initiated whenever said time interval of lean operation drops below a predetermined time interval.

6. A method as claimed in Claim 5, wherein said indicator is energized whenever the time interval between SO<sub>x</sub> purges drops below a predetermined time interval.

7. A method of diagnosing the status of a NO<sub>x</sub> trap disposed in an exhaust passage of an internal combustion engine, comprising a sequence of the following steps:

performing a NO<sub>x</sub> purge on said trap after operating  
5 said engine in a lean mode of operation;

determining the sorption efficiency of said trap;

reducing the time duration of said lean mode of  
operation if said efficiency drops below a predetermined  
level;

10 performing a SO<sub>x</sub> purge on said trap if said time  
duration falls below a predetermined minimum time interval;  
and

providing an indication of trap deterioration if  
the time interval between SO<sub>x</sub> purges is less than a  
15 predetermined time interval.

8. A method as claimed in Claim 7, wherein the NO<sub>x</sub>  
purge is initiated after operating the engine in said lean  
mode for a predetermined time interval.

20

9. A method as claimed in Claim 8, wherein the NO<sub>x</sub>  
purge is terminated based on the oxygen content of the  
exhaust downstream from said trap.

25 10. A method as claimed in claim 7, wherein the  
sorption efficiency is computed by:

determining the amount of NO<sub>x</sub> stored on the trap;

estimating the amount of NO<sub>x</sub> produced by the engine  
during the last lean mode of operation; and

30 dividing the amount of NO<sub>x</sub> stored on the trap by  
the estimated amount of NO<sub>x</sub> produced by the engine.

11. A method as claimed in Claim 10, wherein the determination of the amount of NO<sub>x</sub> stored on the trap is based on the time interval between initiation of said NO<sub>x</sub> purge and detection of a stoichiometric exhaust gas condition downstream of the trap.

12. A vehicle on-board computer diagnostic system for monitoring the status of a NO<sub>x</sub> trap disposed in an exhaust passage of an internal combustion engine comprising :

10 a computer for generating a command to purge said NO<sub>x</sub> trap;

a sensor disposed downstream from said trap;

an indicator;

said computer generating a command to energize

15 said indicator based on the sorption efficiency of said trap.

13. A system as claimed in Claim 12, wherein said sensor is an exhaust gas oxygen sensor.

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14. A system as claimed in Claim 13, wherein said computer generates a NO<sub>x</sub> purge command causing a change in the mixture supplied to said engine from a relatively lean A/F to a relatively rich A/F.

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15. A system as claimed in Claim 14, wherein said sorption efficiency is the ratio of the amount of NO<sub>x</sub> stored on the trap divided by the amount of NO<sub>x</sub> generated by the engine.

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16. A system as claimed in Claim 15, wherein the amount of NO<sub>x</sub> stored on the trap is a function of the trap



temperature and the lean to rich response time of said sensor.

17. A system as claimed in Claim 15 wherein the amount  
5 of NO<sub>x</sub> generated by the engine is a function of engine speed  
and air mass inducted into said engine.

18. A system as claimed in Claim 17, wherein said  
computer increases the frequency of NO<sub>x</sub> purges if the  
10 sorption efficiency drops below a predetermined efficiency.

19. A system as claimed in Claim 18, wherein said  
computer initiates a SO<sub>x</sub> purge if the time between NO<sub>x</sub> purges  
drops below a predetermined time interval.

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20. A system as claimed in Claim 19, wherein said  
indicator is energized if the time interval between SO<sub>x</sub>  
purges drop below a predetermined time interval.

21. A system as claimed in Claim 20, comprising a  
20 second exhaust gas oxygen sensor located upstream of said NO<sub>x</sub>  
trap and said NO<sub>x</sub> purge is terminated when the difference in  
the output of the downstream sensor and the upstream sensor  
is less than a predetermined threshold.

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22. A method of diagnosing the status of a NO<sub>x</sub> trap  
substantially as hereinbefore described with reference to  
and as illustrated in the accompanying drawings.

23. A system for monitoring the status of a NO<sub>x</sub> trap  
30 substantially as hereinbefore described with reference to  
and as illustrated in the accompanying drawings.



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Claims searched: 1-11

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Date of search: 16 January 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.P): G1N NBMH.

Int CI (Ed.6): F01N 7/00

Other: ONLINE: CLAIMS, INSPEC, JAPIO, WPI.

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A, P	EP 0 735 250 A (Toyota Jidosha K K)	1
X, P	EP 0 733 786 A (Toyota Jidosha K K)	
A	EP 0 690 213 A (Toyota Jidosha K K)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.